The role of interchange fees in ATM networks

Jocelyn Donze* and Isabelle Dubec†

November 26, 2003

Abstract

We develop a model to study the deployment of shared automated teller machines (ATMs) by banks when an interchange system compensates them for processing foreign withdrawals. The interchange fee is chosen collectively by banks and it is paid by the withdrawer's bank to the ATM-owning bank. We show that a high level of interchange fee softens competition on the market for deposits but increases competition on the market for withdrawals. As the former effect dominates the latter, profits are increasing in the interchange fee. This confirms the presumption that the interchange system can be used as a collusive device by banks. The model predicts an over-provision of ATMs when the number of banks is large. The predictions of the model are shown to be valid under a wide range of assumptions including different cost structures and different pricing schemes of ATM transactions. They are also consistent with the empirical evidence concerning interchange fees and foreign fees.

JEL No. L1, G2

*GREMAQ, (UMR 5603 CNRS) Toulouse; jdonze@univ-tlse1.fr

†GREMAQ (UMR 5603 CNRS) Toulouse; dubec@univ-tlse1.fr.

We thank Jorge Padilla, Jean-Charles Rochet, François Salanié and Jean Tirole for helpful suggestions.

1 Introduction

Automated teller machines (ATMs) have become an increasingly important way to access cash. Introduced in the 1970s as low-cost substitutes of human tellers, they were initially set up inside or immediately outside the branch offices of a particular bank and could only be used by consumers who already had checking or savings accounts within that bank. Over time, banks realized that they could benefit from important economies of scale by linking up their proprietary networks into regional or national shared networks. A shared network allows a cardholder of a bank to make a "foreign withdrawal" by using her cash card in an ATM held by another bank. A network switch acts as a central device allowing for clearing.[1] In most countries,[2] the contribution of a bank's ATMs to the network is rewarded by an interchange system: when a cardholder of a bank uses an ATM of another bank of the network, the cardholder's bank pays to the ATM-owning bank an interchange fee to compensate it for the costs of deploying the ATM and providing the service.[3] In general, this fee is set collectively by the network members.

Banks pass on the cost of currency distribution to end-users. In some cases, ATM transactions are included in an account based pricing scheme. It can take the shape of periodic access payments or payments of below-market rates of interest. In other cases, consumers of ATM services are charged for usage. In general, the cardholder's bank imposes per transaction fees for the use of ATMs owned by other network members. These fees are known as foreign fees. In some countries, the two systems of pricing coexist : some banks choose a fixed annual fee without usage fees, other banks also charge their cardholders when they

[1] Typically, the network switch is jointly owned by the network banks.

[2] Germany being a notable exception.

[3] Fixed deployment costs include the costs of purchasing the machines and renting space. Fixed operating costs include maintenance and a permanent telecommunication line. Variable operating costs include stocking the machines with cash and the interest foregone on this cash. They also include a switch cost which is the fee paid by the cardholder's bank to the network switch for the cost of routing the transaction information.

make a foreign withdrawal.[4]

Several empirical observations have been made about interchange fees. First, evidence suggests that they involve a substantial mark-up over the average cost of providing ATM services. Second it has been noted that although deployment costs and communication costs have decreased over the past decade, interchange fees have remained largely unchanged. Third, the substantial margin between average costs and interchange fees could have been expected to attract new entrants into the provision of ATM services. Although there have been some new entrants, these have not created downward pressures on interchange fees. Fourth, foreign fees, when they exist, are on average set above the interchange fees.[5]

Economists and antitrust authorities consider the joint determination of prices with suspicion. In the banking sector, they argue that the collective setting of interchange fees explains why they remain sticky above the average cost of providing ATM services.[6]

---

[4]In European countries as France, Great Britain and The Netherlands, foreign fees remain exceptional (see Bolt (2003) for the Netherlands and Ganguly and Milne (2001) for the UK). But they are common in Italy (see Ardizzi and Coppola, (2002)). Note that in the EU, foreign fees could become more frequent to the new EU regulation of July 2002 that states that cardholders must pay the same fee to their bank for any foreign withdrawal wherever in Europe. In Australia, foreign fees are generalized (see Reserve Bank of Australia and Australian Competition and Consumers Commission (2000)). In the United States, 78.5% of banks charge foreign fees. In this country, many ATM owners also impose fees known as "surcharges" on individuals using a card issued by another network member (see Mc Andrews (2003)).

[5]In the United Kingdom, the Cruickshank report, *competition in UK banking* (2000), estimates the average cost of ATM cash withdrawal at 0.2p. compared with interchange fees as high as 0.4p. In Australia, according to the reserve bank and the competition and consumer commission (2000), foreign fee range from A$1.1 to A$2 with an average level of A$1.35, the average interchange fee is A$1.1 and the average cost of ATM cash withdrawal is AU$0.5. In the United States, foreign fees range from $0.25 to $2.5 with an average level of $1.17, interchange fees typically range from $0.34 to $0.65 with an average level of $0.50 and the cost of ATM cash withdrawal is approximately $0.3 (McAndrews (2003)).

[6]In some countries, the regulator has studied the system of interchange fees. In the United Kingdom, the Office of Fair Trading (OFT) has decided that the LINK Network benefits consumers and has granted

In this paper, we analyze how banks choose the interchange fee jointly and how this choice affects the deployment of shared ATMs and the pricing strategies of banks. For this purpose, we set up a model in which banks are differentiated on a Salop's circle (1979). Banks choose the interchange fee collectively but they choose both the number of ATMs to deploy and prices non-cooperatively. They propose two complementary services to their customers: basic banking services (management of deposits, loans, ...) and the access to cash through a shared ATM network. We first consider a pricing scheme in which banks charge a unique annual fee for providing the basic services and free access to all ATMs. Banks compete to attract depositors (cardholders) and to process withdrawals for receiving interchange fees. Banks compete for withdrawals by deploying ATMs. The interchange fee must be larger than the marginal cost of an ATM transaction to provide banks with incentives to deploy ATMs. Besides, increasing the interchange fee has two effects. On the one hand, the competition for processing withdrawals is strengthened, more ATMs are opened and banks' deployment costs increase. On the other hand, each bank is less willing to accept depositors as the foreign withdrawals they would make induce high interchange outflows. Consequently banks increase their retail prices and their revenues raise. We show that the positive effect on revenues dominates the negative effect on costs so that banks' profits are increasing in the interchange fee. Hence, the interchange fee is not simply a transfer payment as it can be used by banks as a collusive device. Thereafter, we focus on the process by which banks choose the interchange fee collectively. For this purpose, we introduce a condition to guarantee the stability of the shared network. Under this condition,

an unconditional exemption under Chapter I of the Competition Act 1998. The arbitrator has felt that interchange fees are necessary to guarantee universal access to ATMs and are mainly a transfer payment to equilibrate the costs and benefits between the cardholders' banks and the ATM owners. In 2000, the australian competition commission studied the role of interchange fees and proposed to replace them by a scheme in which the ATM owners charge the cardholders of other banks (direct charging). We will briefly compare the two schemes thereafter.

no bank should be unilaterally willing to turn to “one-way compatibility”, defined as the situation in which a bank prevents its cardholders from making foreign withdrawals while it accepts the withdrawals made by cardholders of other banks. While a high interchange fee permits more collusion between banks, it also fosters unilateral deviations to one-way compatibility since banks want to avoid high interchange payment outflows. We examine the welfare properties of this collective decision process. In most cases, the number of ATMs deployed at equilibrium is under optimal when there are only two banks. However this number always exceeds the social optimum when the number of banks is large enough. For a bank, switching to one-way compatibility is feasible if the difference between consumers' valuations of the shared and proprietary networks is not too large. It is generally the case with two banks, and a small interchange fee must be chosen to prevent deviations to one-way compatibility. In this case, the total network size is small and below the optimal level. With a large number of banks, the difference between consumers' valuations is quite large and deviating profitably to one-way compatibility is more difficult. Consequently, a higher interchange fee can be chosen, the network is large and too many ATMs are deployed compared to the social optimum. We show the previous results are valid under a wide range of assumptions that includes for example the shape of deployment costs. We also consider another pricing scheme where banks set a two part tariff composed of a fixed fee and a foreign fee. Using a particular demand for foreign withdrawals, we construct an interchange scheme that implements the same equilibrium outcome as the one without foreign fees.

The paper is organized as follows. In section 2, we review the literature. In section 3, we set up the model. In section 4, we solve the stages where banks deploy ATMs and compete for depositors. Section 5 deals with the process by which banks jointly choose the interchange fee and its welfare properties are studied. In section 6, we extend the model to the case banks charge foreign fees. Section 7 concludes.

2 Related literature

Our work is related to several recent contributions on ATM networks, on telecommunication industries, and on payment networks.

ATM networks

A part of the literature on ATMs deals with the formation of compatible networks. McAndrews and Rob (1996) model the ATM industry as a vertical structure of production. Banks in the downstream industry sell ATM services to cardholders and buy switch services from two incompatible ATM processing networks. Banks choose the network they want to join. The authors explain why joint ownership networks are more attractive for banks than solely owned networks. Rather than studying network formation or competition between networks to attract banks, we focus on competition between banks belonging to the same shared network. In this framework the pricing of interchange flows is the main determinant of ATM deployment. Matutes and Padilla (1994) study the incentives of banks to share their networks while they compete for depositors. Network compatibility has two opposite effects on the competition for depositors. Cardholders are willing to accept a lower interest rate on their accounts because compatibility lowers transportation costs to withdraw cash. However, compatibility makes banks more substitute: a depositor can credibly threaten its bank to switch to a rival offering a better rate and still benefits from the convenient location of the bank's ATMs. This substitution effect makes compatibility less attractive for banks. The authors note that introducing an interchange fee in their model would lower this substitution effect. In this case, banks are less eager to accept additional depositors because of their costly foreign withdrawals. Hence, interchange fees make sharing more attractive. We start from this result by assuming a shared network structure. However we endogenize both the collective choice of the interchange fee by banks and the deployment of ATMs.

A part of the literature deals with ATM pricing in shared networks. In Massoud and

Bernhardt (2002), cardholders pay a direct charge to the ATM owning bank and a fixed account fee to their affiliated bank. There is no interchange fee. At equilibrium, the two banks discriminate according to the cardholders' affiliation. The ATM usage fee is set at marginal cost for the bank's customers in order to maximize the surplus that can be extracted through the fixed account fee. The usage fee is set above the marginal cost for non-customers. Massoud and Bernhardt (2001) endogenize the ATM deployment. They show that discriminating according to the cardholders' affiliation generates an over-provision of ATMs compared to the social optimum. As the consumer surplus is more efficiently extracted through the fixed account fee, banks compete for a larger customer base by over-providing ATMs and by setting high usage fees for non-customers. Contrarily to the purely noncooperative framework of Massoud and Bernhardt, our work studies the deployment of ATMs when banks have jointly chosen the interchange fee. Croft and Spencer (2003) consider two banks with different customer bases but equal exogenous fleets of ATMs. Banks set the interchange fee jointly and foreign fees non cooperatively. The authors find conditions under which banks would voluntarily agree not to surcharge. They show that the bank with the larger customer base prefers lower interchange fees and a ban on surcharges. Under this ban, banks with equal customer bases set the interchange fee at marginal cost which implements a joint profit maximizing foreign fee. In our model, compatibility inside the shared network generates positive externalities : each ATM deployed by a bank benefits to both its own customers and its competitors. The interchange system is a reward for providing competitors' cardholders with cash. Consequently, the optimal interchange fee must be above the marginal cost of providing cash to avoid free riding behaviors. Furthermore, we show that by choosing a high interchange fee, banks soften the competition for depositors.

Telecommunication Industry

Laffont, Rey and Tirole (1998a) develop a model of unregulated competition between interconnected telecommunication networks. Networks pay access termination charges to each other and compete for customers under a nondiscriminatory pricing scheme. They show that the retail price increases with the access charge: a higher access price softens the competition for customers as their off-net calls are more costly.[7] In the ATM industry, the interchange fee is an access price. Consequently, a high interchange fee also softens competition for depositors because their foreign withdrawals are more costly. However, there is one important distinction between telecommunication and ATM industries. While the access price has no effect on the quality of the telecommunication network, the level of the interchange fee affects the deployment of ATMs. Hence, increasing the interchange fee lowers competition for depositors but also increases the deployment costs. One of our main contributions is to show that for a large class of deployment costs, the positive effect on profits outweighs the negative one so that the interchange fee can also be used as a collusive device.

Payment systems

Payment systems and ATM networks work differently. In a payment system, the volume of transactions is determined on a two sided market: issuer banks and cardholders on one side and acquirer banks and merchants on the other side. These agents interact through indirect network effects. A card is more valuable to customers when more merchants are ready to accept it, and accepting a particular card is more valuable for a merchant when more consumers carry it and use it. As modelled by Rochet and Tirole (2001), the system has to attract both sides of the market taking into account the likely resistance of the merchants to the payments by cards. The ATM industry does not exhibit any indirect network effect since there is only one kind of end-user: the cardholder.

[7] See Armstrong (2002) for a clear overview of the theory of access pricing and interconnection.

3 The model

Banks and consumers of banking services are involved in the game. The model uses a framework à la Salop (1979). Consumers are horizontally differentiated in a product space: they are uniformly distributed on a circle of unitary size. The number of consumers is normalized to one.

Banks. There are b *banks* located at an equal distance from one another on the circle. They deploy compatible ATMs. The number of ATMs deployed by bank i is $n_i \in \Re^+$. The total size of the network is $n = \Sigma_{i=1}^{b} n_i$.[8] The fixed costs of deploying and operating an ATM are denoted by c. Each bank proposes a package of banking services composed of

- Basic services directly provided by the bank: deposits management, the possibility to withdraw cash at the bank branch, etc.
- A debit card allowing to withdraw cash at any ATM of the shared network.

The price of the package proposed by bank i is p_i. The marginal cost of basic services is constant and normalized to zero. We assume that the marginal cost to process a withdrawal is constant and independent of the affiliation of the cardholders. It is denoted by s.

When a customer of bank i makes a withdrawal at an ATM of bank j, bank i pays an interchange fee, a, to bank j. We assume that banks choose the interchange fee collectively.

Consumers. They choose the bank they want to become a cardholder of. The net surplus of a consumer buying the package of bank i located at distance d_i is

$$v_b + v(n) - td_i - p_i$$

[8] As the number of consumers is normalized to one, n and the n_is can be interpreted as ATM densities in relation with cardholder population.

The parameter t represents the degree of differentiation in the product space. The term v_b is the gross surplus from getting basic banking services. We assume that v_b is large enough to guarantee full coverage of the market. The term $v(n)$ is the gross surplus from getting access to a network composed of n ATMs. We assume that $v(n)$ is strictly increasing and strictly concave with $v(0) = 0$. Indeed increasing the size of the network benefits customers because transportation costs to withdraw cash are reduced. Nevertheless the marginal benefit decreases as the network size increases.

Each cardholder makes w withdrawals of a fixed amount. We assume that $w\frac{n_i}{n}$ is the total number of withdrawals made at bank i's ATMs. Indeed, we have in mind a framework in which banks' ATMs are uniformly located in a urban setting so that only ATM densities determine how consumers distribute their withdrawals.

Timing of the game. First, banks decide interconnection agreements by choosing the interchange fee a collectively; Second, knowing the interchange fee, they simultaneously and non-cooperatively choose the number of ATMs they open, n_i , $i = 1, ...b$. Third, knowing the interchange fee and the number of ATMs deployed, banks simultaneously and non-cooperatively choose the prices of the packages, p_i, $i = 1, ...b$. Fourth, each consumer chooses her bank and makes the withdrawals.

We assume that the collective setting of the interchange fee is made before the deployment of ATMs for two main reasons. First, the interchange fee can be thought as being part of the standards defining the shared network. Second, the collective setting of the interchange fee is time consuming and unwieldy. However, we will argue that our results also hold when banks have an installed base of ATMs before setting the interchange fee.

4 Competition for deposits and withdrawals.

We look for the subgame perfect equilibrium of the model by solving the game by backward induction. Because of the assumption that v_b is large, we can focus on the case in which the market is fully covered. Furthermore, we deal with the case in which the interchange fee a is larger than the marginal processing cost, s.

Price competition.

At the third stage of the game, the level of the interchange fee and the number of ATMs deployed by banks are given. Let $\widetilde{d_i}$ denote the distance between bank i and the consumer who is indifferent between purchasing services from bank i or $i+1$:

$$v(n) - t\widetilde{d_i} - p_i = v(n) - t(\frac{1}{b} - \widetilde{d_i}) - p_{i+1} \tag{1}$$

Bank i's market share of deposits is:

$$D_i = \frac{1}{b} + \frac{p_{i+1} + p_{i-1} - 2p_i}{2t}$$

Note the deposit market share of bank i does depend neither on the number of ATMs of bank i nor on the total network size. This is due to the fact that the network is shared and freely accessible. The profit of bank i is:

$$\pi_i = p_i D_i - a\frac{n - n_i}{n} D_i w + a\frac{n_i}{n}\left(\sum_{j \neq i} D_j\right) w - s\frac{n_i}{n} w - cn_i \tag{2}$$

The first term of the right hand side of expression (2) is the revenue from selling packages. The second term is the cost coming from the interchange fees paid to other banks when bank i's cardholders make foreign withdrawals. The third term is the revenue coming from the interchange fees paid by other banks when their cardholders use an ATM of bank i. The two last terms represent the total processing costs and the deployment costs. The profit of bank i can be rewritten as

$$\pi_i = p_i D_i + a(\frac{n_i}{n} - D_i)w - s\frac{n_i}{n} w - cn_i \tag{3}$$

to show the net value of interchange flows, $a(\frac{n_i}{n} - D_i)w$. This value is positive as long the ATM market share of bank i is larger than its deposit market share.

Bank i maximizes its profit with respect to p_i. The first order condition gives:

$$p_i = \frac{1}{4}(p_{i+1} + p_{i-1} + \frac{2t}{b} + 2aw).$$

By solving the b first order conditions simultaneously, we get the following characterization of the equilibrium of the third stage of the game:

Proposition 1 *At the unique and symmetric equilibrium of the third stage of the model, prices are*

$$p_i^*(a) = \frac{t}{b} + aw \textit{ for } i = 1, ..., b$$

The expression of equilibrium prices has two parts as in the Salop's model. The first part, $\frac{t}{b}$, leads to the usual comments: it is increasing in the differentiation parameter, t, because more differentiation increases banks' local monopoly power. It is decreasing in the number of banks, b, as more banks strengthen competition for depositors. The second part, aw, represents bank i 's total cost of producing and selling a package to one customer. It is the sum of two elements: a direct cost, $\frac{n-n_i}{n}aw$, due to the payments of interchange fees for the foreign withdrawals realized by this customer, and an opportunity cost, $\frac{n_i}{n}aw$, which is the amount of interchange fees that bank i would receive if this customer chose another bank.

ATMs deployment.

We now turn to the second stage of the game in which banks deploy ATMs knowing the level of the interchange fee. Bank i maximizes its profit $\pi_i = \frac{t}{b^2} + (a - s)\frac{n_i}{n}w - cn_i$ with respect to n_i. The first order condition is

$$(a - s)\frac{n - n_i}{n^2}w = c \tag{4}$$

Combining the b first order conditions gives the following result:

Proposition 2 *At the unique and symmetric equilibrium of the second stage of the game, the number of ATMs deployed by each bank is strictly increasing in the interchange fee a:*

$$n_i^*(a) = \frac{a-s}{c}\frac{b-1}{b^2}w \ , \ i = 1, ...b \tag{5}$$

The total size of the network is

$$n^*(a) = \frac{a-s}{c}(1-\frac{1}{b})w$$

Not surprisingly, the number of ATMs deployed by each bank is decreasing in the deployment cost c. More interestingly, this number is increasing in the interchange fee a. It is equal to zero if the interchange fee is equal to the marginal cost of processing a withdrawal. In this case, each bank free rides on the other banks. If the interchange fee is above s, then banks compete for withdrawals: banks open ATMs to limit the number of foreign withdrawals made by their cardholders and to attract withdrawals made by their competitors' cardholders. While the number of ATMs deployed by each bank is decreasing in the number of banks, the total network size $n^*(a)$ is increasing in b. The properties of the equilibrium profit function are given in the following proposition:

Proposition 3 *The profit of each bank is a strictly increasing function of the interchange fee a:*

$$\pi_i^*(a) = \frac{t}{b^2} + \frac{a-s}{b^2}w \ , \ i = 1, ...b$$

Increasing the interchange fee has two effects on banks' profits. There is a negative effect due to a strengthened competition to attract withdrawals. More ATMs are deployed and banks' costs increase. There is also a positive effect: higher interchange fees allow higher prices and hence a more collusive behavior of banks on the market for deposits. This leads to higher revenues. The increase in revenues outweighs the increase in costs and, thereby, profits increase. Hence, interchange agreements are potentially an instrument of tacit collusion. Furthermore, the positive effect of the interchange fee on profits appears although at equilibrium the accounting outflows and inflows are perfectly balanced.[9]

The results of propositions (2) and (3) hold in the three following variants of the model:

- **Banks with convex deployment costs.** Let us assume that the cost of deploying n_i ATMs is $c(n_i)$ with $c'(n_i) > 0$ and $c''(n_i) \geq 0$. In the ATM industry, this shape of cost arises naturally due to the existence of capacity constraints. In this case, the number of ATMs deployed by bank i, $n_i^*(a)$, is determined implicitly as the solution of expression (5) in which c is replaced by $c'(n_i^*(a))$. $n_i^*(a)$ and $\pi_i^*(a)$ are increasing functions of the interchange fee. Indeed $\left.\frac{dn_i^*}{da}\right|_{eq} = \frac{b-1}{b^2}\frac{1}{c'(n_i)+n_i c''(n_i)}w$ which is positive when $c''(.)$ is non negative. Furthermore, the first derivative with respect of a of bank i 's profit function, $\pi_i^* = \frac{t}{b^2} + \frac{(a-s)w}{b} - c(n_i^*)$ is $\left.\frac{d\pi_i^*}{da}\right|_{eq} = \frac{w}{b} - c'(n_i^*)\frac{dn_i^*}{da} = \frac{w}{b}\left(1 - \frac{b-1}{b}\frac{c'(n_i)}{c'(n_i)+n_i c''(n_i)}\right)$ which is strictly positive when $c''(.)$ is non negative.

- **Banks with asymmetric installed base of ATMs.** Let us assume that before setting the interchange fee collectively, each bank i already has k_i ATMs installed. At the third stage of the game, the equilibrium prices are clearly unchanged. At the deployment stage, the benefit for bank i of deploying an additional ATM is:

  $$(a-s)\frac{(n+k)-(k_i+n_i)}{(n+k)^2}w$$

  with $k = \sum_{j=1}^{b} k_j$. As the marginal cost is constant we have:

  $$k_i + n_i^*(a) = \frac{a-s}{c}\frac{b-1}{b^2}w \text{ for } i = 1, ..., b$$

  Symmetry is restored at the deployment phase.

- **Asymmetric locations of banks**. Suppose that banks are not equidistant on the circle. In this case, the retail prices of the third stage are different because they reflect

[9] Because of the symmetry of the equilibria of the second and third stages, there is equality between ATM market shares and deposit market shares.

the market power of banks. The market shares of depositors are unequal but they still do not depend on the ATM network size. If D_i is the equilibrium deposit market share of bank i, differentiating expression (2) with respect to n_i gives the following condition:

$$(a-s)\frac{n-n_i}{n^2}D_i w + (a-s)\frac{n-n_i}{n^2}(\Sigma_{j\neq i}D_j)w = c \tag{6}$$

The left hand side is the extra revenue for bank i coming from an additional ATM. This revenue comes from each withdrawal newly processed and it is independent from the affiliation of the withdrawer. It is equal to the interchange inflow when the withdrawer is not a cardholder of bank i and it is the interchange outflow saved by bank i otherwise. Expression (6) is clearly equivalent to expression (4). Therefore, under our non-discriminatory pricing scheme, banks' incentives to deploy ATMs do not depend on their deposit market share. As a consequence, each bank deploys the same number of ATMs as in the symmetric case.[10]

It is worth stressing that introducing asymmetries as in the two last points does not affect the symmetry of the deployment equilibrium. In our model, banks deploy different numbers of ATMs *only when* they have different deployment costs. In this case, a bank with lower deployment costs opens more ATMs. One can think it is the case for banks with many branches because typically, an ATM located at a bank's branch is deployed and operated at lower costs.

In the next section, we focus on the process by which banks choose the interchange fee collectively.

[10]Suppose there are non bank firms located outside the circle, with no depositors, that just deploy ATMs and receive interchange fees. The previous result implies that if these firms have the same deployment costs as depository institutions, they deploy the same number of ATMs.

5 Collective setting of the interchange fee and welfare analysis

Banks jointly choose the interchange fee anticipating the number of ATMs and the retail prices that result from this choice. As profits are increasing in the interchange fee, banks want to set it at the highest possible level. In this section, we introduce a condition to guarantee that the chosen interchange fee is consistent with the stability of the network and we discuss the welfare properties of the equilibrium.

5.1 The collective choice of the interchange fee

We assume that the network wants to guarantee the stability of its shared structure by preventing unilateral deviations to "one-way compatibility" at the third stage of the game. One-way compatibility is defined as a situation in which one bank prevents its cardholders from making foreign withdrawals while still delivering cash to other banks' cardholders. A high interchange fee fosters unilateral deviations to one-way compatibility because by deviating, banks avoid the payment of high interchange outflows.

We look at the situation in which bank i switches to one-way compatibility at the third stage of the game. The price proposed by bank i is denoted by p_i^d. Let $\widetilde{d_i}$ denotes the distance between bank i and the consumer who is indifferent to whether she purchases services from bank i or from the other closest bank. We have:

$$v\left(n_i^*(a)\right) - t\widetilde{d_i} - p_i^d = v\left(n^*(a)\right) - t(\frac{1}{b} - \widetilde{d_i}) - p^*(a)$$

with $p^*(a) = \frac{t}{b} + wa$, since the other banks do not deviate from the price of "full compatibility". We have:

$$\widetilde{d_i} = \frac{1}{2t}\left(p^*(a) - p_i^d - \Delta v + \frac{t}{b}\right)$$

with

$$\Delta v = v\left(\frac{a-s}{c}\frac{b-1}{b}w\right) - v\left(\frac{a-s}{c}\frac{b-1}{b^2}w\right)$$

Δv represents consumers' valuation of compatibility: it is the loss of surplus for a cardholder who switches from the shared network to bank i's proprietary network. The demand addressed to bank i after deviating is:

$$D_i^d = \frac{1}{b} + \frac{1}{t}\left(p^*(a) - p_i^d - \Delta v\right)$$

Bank i increases its market share if the loss of consumers' surplus is outweighed by the price decrease. The profit of bank i is:

$$\pi_i^d = (p_i^d - sw)D_i^d + (a-s)\frac{1}{b}(1-D_i^d)w - cn_i^*(a) \tag{7}$$

Note that bank i receives flows of interchange fees without paying any. Differentiating expression (7) in p_i^d gives:

$$p_i^d = \frac{t}{b} + \frac{b+1}{2b}wa - \frac{\Delta v}{2} + \frac{b-1}{2b}ws$$

Note that as a is larger or equal to s, p_i^d is smaller than $p^*(a)$. The deviation profit is:

$$\pi_i^d(a) = \frac{1}{4t}\left((a-s)\frac{b-1}{b}w + \frac{2t}{b} - \Delta v\right)^2 + \frac{(a-s)w}{b} - cn_i^*(a)$$

Bank i is not willing to deviate if $\pi_i^d(a)$ is smaller than the equilibrium profit:

$$\pi_i^*(a) = \frac{t}{b^2} + \frac{(a-s)w}{b} - cn_i^*(a)$$

We find the following condition of no deviation:

$$v\left(\frac{a-s}{c}\frac{b-1}{b}w\right) - v\left(\frac{a-s}{c}\frac{b-1}{b^2}w\right) \geqslant (a-s)\frac{b-1}{b}w \tag{8}$$

The left hand side of condition (8) is consumers' valuation of compatibility. It is the loss of consumers' surplus when switching to one-way compatibility. It can also be interpreted as the price decrease that the deviator must grant to compensate this loss and maintain its deposit market share. The right hand side of condition (8) represents the savings (per consumer) of interchange outflows due to switching to one-way compatibility. Hence, condition (8) shows that deviating unilaterally to one-way compatibility is not profitable for firms as long as the savings of interchange outflows are smaller than the loss due the price decrease.

Profits being increasing in the interchange fee, banks choose the highest possible a subject to constraint (8). To guarantee there exists a unique solution, a^*, strictly larger than s, we assume that for any integer $b \geq 2$, equation

$$v(n) - v(\frac{n}{b}) = cn \tag{9}$$

has a unique positive solution, denoted n^*. n^* is the total network size coming from the collective choice of banks. Furthermore, we make the technical assumption that $\lim_{n \to 0} v'(n) - \frac{1}{b}v'(\frac{n}{b}) > c$. It is convenient to give results concerning n^* before those concerning a^*. In this case the properties of a^* will be derived from n^* using the following formula:

$$a^* = s + \frac{b}{b-1}\frac{c}{w}n^* \tag{10}$$

n^* is illustrated on figure 1 for two different cases.

(Insert Figure 1 here)

In part (a) of figure 1, consumers' valuation of compatibility is an increasing function of n. It is the case with the function $v(n) = \alpha n^{\beta}$ (for any $\alpha > 0$ and $0 < \beta < 1$). In part (b) of figure 1, consumers' valuation of compatibility is first increasing and then decreasing. That means that when the number of ATMs becomes large, the value of the proprietary network gets closer to the value of the shared network. It is the case with the function $v(n) = \frac{\alpha n}{n+\beta}$ (for any $\alpha, \beta > 0$). The properties of n^* are described in the following proposition:

Proposition 4 *The total number of ATMs deployed as a consequence of the fee collectively chosen by banks, n^*, is decreasing in the deployment cost, c. It is increasing in the number of banks, b.*

Proof. At equilibrium, we have $c > v'(n^*) - (1/b)v'(n^*/b)$. Differentiating expression (9) gives $\frac{dn^*}{dc}\big|_{eq} = \frac{-n^*}{c-(v'(n^*)-(1/b)v'(n^*/b))} < 0$ and $\frac{dn^*}{db}\big|_{eq} = \frac{v'(n^*/b)n^*/b^2}{c-(v'(n^*)-(1/b)v'(n^*/b))} > 0$ ■

The first part of proposition 4 states that lower deployment costs lead to a larger network size: keeping the network size constant with a smaller c would make the savings of interchange fees associated to one-way compatibility (the RHS of expression (9)) smaller than the compensating price decrease (the LHS of expression (9)). The effect of the deployment cost on the value of the interchange fee is less evident. Differentiating expression (10) with respect to c gives:

$$\frac{da^*}{dc}\bigg|_{eq} = \frac{b}{b-1}\frac{n^*}{w}\left(1 + \frac{c}{n^*}\frac{dn^*}{dc}\bigg|_{eq}\right) \tag{11}$$

Hence, the effect of the deployment cost on the interchange fee depends on the value of the ATM supply elasticity with respect to the deployment cost. This value is equal to

$$\frac{c}{n^*}\frac{dn^*}{dc}\bigg|_{eq} = \frac{-c}{c - \left(v'(n^*) - \frac{1}{b}v'(\frac{n^*}{b})\right)}$$

If $v'(n^*) - \frac{1}{b}v'(\frac{n^*}{b}) > 0$ then the value of this elasticity is lower than minus one. In this case, $\frac{da^*}{dc}\big|_{eq} < 0$: lower deployment costs lead to the choice of a higher interchange fee. Note that a simple and sufficient condition to guarantee the inequality is that $v(n) - v(n/b)$ is increasing in n. This is for example the case for the function $v(n) = \alpha n^\beta$ (for any $\alpha > 0$ and $0 < \beta < 1$).

If $v^{'}(n^*) - \frac{1}{b}v'(\frac{n^*}{b}) < 0$ then the value of this elasticity is higher than minus one. In this case, $\frac{da^*}{dc}\big|_{eq} > 0$: lower deployment costs lead to the choice of a lower interchange fee. This case is illustrated in part (b) of figure 1.

The two previous results can be interpreted as follows. For a fixed level of interchange fee, expression (5) states that lower deployment costs fosters the deployment of ATMs. If the additional ATMs increase consumers' valuation of compatibility, then switching to one-way compatibility becomes harder and a higher interchange fee can be chosen. When the additional ATMs reduces consumers' valuation of compatibility, switching to one-way compatibility becomes easier and a lower interchange fee must be chosen.

The second part of proposition 4 suggests that the unilateral threats of turning to one-way compatibility are less credible when more banks compete. Indeed, more banks make consumers' valuation of compatibility larger and switching to one-way compatibility is harder. Hence the constraint on the network size that prevents deviations can be relaxed and banks can deploy more ATMs. Note that in this case, enlarging the network does not necessarily require a higher interchange fee since the number of ATMs is also increasing in the number of banks. Differentiating expression (10) with respect to b gives

$$\left.\frac{da^*}{db}\right|_{eq} = \frac{c}{w}\frac{n^*}{b-1}\left(-\frac{1}{b-1} + \frac{b}{n^*}\frac{dn^*}{db}\right) \tag{12}$$

Hence, the collectively chosen interchange fee is increasing in the number of banks when the elasticity of the ATM supply with respect to the number of banks is large enough. This is for example the case for the gross surplus function $v(n) = \alpha n^\beta$ (for any $\alpha > 0$ and $0 < \beta < 1$).

The predictions on a^* are consistent with empirical observations that interchange fees have remained unchanged despite the fact that deployment costs have decreased or that new banks have entered the ATM market.

5.2 Welfare analysis

We compare n^*, the equilibrium size of the network to n^o, the size corresponding to the maximization of the total surplus, $v(n) - cn$. The optimal n^o satisfies

$$v'(n^o) = c \tag{13}$$

At the optimum, the marginal benefit of deploying one ATM must be equal to the marginal cost. The properties of optimality of the equilibrium depends on the number of banks.

Proposition 5 *Suppose there are b banks. If for all $n \geq 0$,*

$$\frac{nv'(n)}{v(n)} > \frac{v(n) - v(\frac{n}{b})}{v(n)} \tag{14}$$

then $n^* < n^o$: the number of ATMs is too small compared to the optimum.

Proof. Using conditions (9) and (13), we can write that $v'(n^o) = \frac{v(n^*)-v(n^*/b)}{n^*} = c$. If condition (14) is satisfied then $v'(n^*) > v'(n^o)$ so that $n^* < n^o$. ■

The left hand side term of inequality (14) is the surplus elasticity. The right hand side term is the relative variation of cardholders' surplus when switching to one-way compatibility. The equilibrium number of ATMs is under-optimal when the two following conditions are met. First, the surplus elasticity must be sufficiently large. In this case, a regulator would choose a large network size. Second, $\frac{\Delta v}{v}$ must be small enough: a small consumer's valuation for compatibility makes banks collectively choose a small network size to avoid unilateral deviations to one-way compatibility. With two banks, inequality (14) is satisfied for many standard surplus functions. It is for example the case for $v(n) = \alpha n^\beta$ (for any $\alpha > 0$ and $0 < \beta < 1$) or for $v(n) = \frac{\alpha n}{n+\beta}$ (for any $\alpha, \beta > 0$).

When the number of banks tends to infinity,the total number of ATMs, n^* deployed after the first stage is given by

$$\frac{v(n^*)}{n^*} = c$$

Using the concavity of $v(n)$ to compare n^* with n^o gives the following proposition:

Proposition 6 *When the number of banks is very large, the number of ATMs deployed at equilibrium is too large compared to the optimum:* $n^* > n^o$.

When deploying ATMs banks are mainly interested by the possibility of collusion. They are not directly concerned by the well being of consumers. When the number of banks is large, the unilateral threat of turning to one-way compatibility is less credible because consumers' valuation of compatibility is high. As a consequence, too many ATMs are deployed compared to the social optimum.

If inequality (14) is verified for $b = 2$, there clearly exists a (possibly non-integer) threshold b^o such that the equilibrium number of ATMs is underoptimal if the number of banks is below b^o and overoptimal otherwise. b^o is defined the solution of $n^o = n^*(b^o)$ where $n^*(b)$ is the solution of (9). Clearly, b^o is in general a function of both $v(.)$ and c. Interestingly, with $v(n) = \alpha n^\beta$, simple calculations show that b^o only depends on β: $b^o = \left(\frac{1}{1-\beta}\right)^{1/\beta}$. b^o is increasing in β, its lower limit is $e \simeq 2.7$, it is equal to 4 when $\beta = 1/2$ and close to 6.35 for $\beta = 3/4$. In this case, for a large range of parameters, optimality is approached if the number of banks is quite small.

6 Foreign fees

In this section, we generalize the previous model to the case there are foreign fees: consumers are charged by their bank for each withdrawal made at an ATM of another bank. We consider the following simple withdrawal behavior. There exists an exogenous reservation fee denoted by $\overline{f}$. When the foreign fee chosen by bank i is below $\overline{f}$, it exerts no influence on the way consumers of bank i withdraw cash; in this case only the densities of ATMs matters as previously. However, when choosing their bank consumers take into account the expected amount of foreign fees they will pay. When the foreign fee is above $\overline{f}$, consumers do not make foreign withdrawals.

This generalization is interesting in two aspects. First, we show our previous results still hold in the extension: the interchange fee collectively chosen by banks and the number of ATMs deployed are the same as before. Second, the extension provides an endogenous explanation to the condition of no deviation to one-way compatibility we used in section 5.

Introducing foreign fees gives banks the possibility to deviate both at the deployment stage and at the pricing stage by choosing a foreign fee above $\overline{f}$. For this reason, we slightly change the scheme defining the interchange fee to keep the model tractable. The game proceeds as follows. At the first stage, banks jointly choose a scheme that gives the value of the interchange fee as a function of the number of ATMs that will effectively be deployed by each bank thereafter: $a = a(n_1, ...n_b)$. At the second stage, banks deploy ATMs. At the third stage, each bank i proposes its cardholders the tariff $T_i = p_i + f_i w_i^f$ where p_i is the fixed account fee, f_i is the foreign fee charged by bank i, and w_i^f is the number of withdrawals that the cardholder of bank i makes at an ATM of another bank. Let us denote by w_i^d the number of withdrawals that this cardholder makes at an ATM of bank i.

Given the tariffs $\{T_i\}_{i=1}^b$, consumers choose a bank by comparing the surpluses of services (including withdrawals) they get. These surpluses depend on the expectations of consumers on the way they withdraw cash. If $\overline{f}$ denotes the reservation fee associated to foreign withdrawals, we assume that bank i's cardholder anticipates that she will make the following number of domestic and foreign withdrawals:[11]

$$(w_i^d, w_i^f)(f_i) = \begin{cases} (\frac{n_i}{n}w, \frac{n-n_i}{n}w) & \text{for} \quad f_i < \overline{f} \\ (w, 0) & \text{for} \quad f_i \geq \overline{f} \end{cases}$$

Given the withdrawal behavior, we define the net expected surplus of an individual

[11] We could make $\overline{f}$ depend on i without altering the nature of our results. In this case, $\overline{f}_i$ can be interpreted as the average transportation cost that bank i's customer has to bear to find the closest ATM of her bank.

becoming a customer of a bank i located at a distance d_i as:

$$\begin{cases} v_b + v(n) - p_i - f_i \frac{n-n_i}{n} w - td_i & \text{if} \quad f_i < \overline{f} \\ v_b + v(n_i) - p_i - td_i & \text{if} \quad f_i \geq \overline{f} \end{cases}$$

Hence, below $\overline{f}$, the *gross* surplus of the consumer depends on $v(n)$ because her withdrawal behavior is unchanged and she still get satisfaction from the entire network. However, note the *net* surplus takes into account the expected amount of foreign fees paid by the consumer. Above $\overline{f}$, the consumer of bank i does not make foreign withdrawal and the gross surplus simply takes into account the size of bank i's proprietary network, $v(n_i)$.

To get the intuitions of how the previous changes alter our results, we first focus on the case where each bank choose "full compatibility", that is $f_i < \overline{f}$ for any i. Thereafter, we study the way to sustain this outcome at equilibrium. It is convenient to write the problem as a function of $T_i \equiv p_i + f_i \frac{n-n_i}{n} w$. In this case, bank i's market share of deposits is

$$D_i = \frac{1}{b} + \frac{T_{i+1} + T_{i-1} - 2T_i}{2t}$$

The profit of bank i is

$$\pi_i \quad = \quad T_i D_i - a\tfrac{n-n_i}{n} D_i w + a\tfrac{n_i}{n} \left(\textstyle\sum_{j \neq i} D_j \right) w - s\tfrac{n_i}{n} w - cn_i$$

Using a change of variable, we can maximize the profit of bank i with respect to T_i and we obtain $T_i \equiv p_i + f_i \frac{n-n_i}{n} w = \frac{t}{b} + aw$ (with $f_i < \overline{f}$).

We now define a pricing scheme and strategies that constitute a subgame perfect equilibrium of the game. At equilibrium, the equilibrium value of the interchange fee is a^*, banks choose the same number of ATMs as in section 4, and foreign fees are below $\overline{f}$. Let us consider the following strategies,

- For any $(n_1, ...n_b)$, the scheme defining the interchange fee is[12]

$$a(n_1, ...n_b) = \begin{cases} a^* \text{ if } n_1 = ... = n_b = \frac{a^*-s}{c}\frac{b-1}{b^2}w \\ s \text{ otherwise} \end{cases} \tag{15}$$

where a^* is the solution of (10).

- For $i = 1, ...b$, $n_i^* = \frac{a^*-s}{c}\frac{b-1}{b^2}w$
- For any $(n_1, ...n_b)$, $\begin{cases} T_i^*(n_1, ...n_b) \equiv p_i^*(n_1, ...n_b) + f_i^*(n_1, ...n_b)\frac{n-n_i}{n}w = \frac{t}{b} + a(n_1, ...n_b)w \\ f_i^*(n_1, ...n_b) < \overline{f} \end{cases}$

We have the following result :

Proposition 7 *The strategies defined above constitute the unique subgame perfect equilibrium of the model given the scheme (15). At equilibrium, the number of ATMs deployed is*

$$n_i^* = \frac{a^*-s}{c}\frac{b-1}{b^2}w, \ i = 1, ...b$$

and the two part tariff is

$$T_i^* \equiv p_i^* + f_i^*\frac{b-1}{b}w = \frac{t}{b} + a^*w \textit{ with } f_i^* < \overline{f}, i = 1, ...b$$

Proof. See appendix. ■

Proposition (7) says that the fixed fee and the foreign fee act as substitutable tools: because of the competition between banks, any increase of the latter must come at the expense of a decrease of the former. Interestingly, the equilibrium of the pricing stage can be asymmetric : some banks choose a scheme in which there is a high fixed fee without any foreign fee : $p_i^* = \frac{t}{b} + a^*w$ and $f_i^* = 0$. Other banks choose a smaller fixed fee with a

[12] For the sake of clarity, we use the simplest interchange scheme that works. One could quite easily construct a continuous scheme.

positive foreign fee. This prediction is consistent with the observation that in some countries different ATM pricing strategies coexist. Among the family of tariffs with positive foreign fees, the tariff $p_i^* = \frac{t}{b}$ and $f_i^* = \frac{b}{b-1}a^*$ is interesting since it is consistent with the situation of countries in which the foreign fees are set above the interchange fee.

7 Summary and concluding remarks

We have developed a model to analyze how the choice of interchange fee by banks affects the deployment of ATMs and the pricing of banking services. In this model, the jointly choice of the interchange fee, the ATM deployment and the competition for depositors are endogenous. Our work clearly shows that the deposit market and the withdrawal market must be studied simultaneously: a high interchange fee strengthens the competition for withdrawals but softens the competition for deposits. The latter effect dominates the former one and consequently, the interchange fee can be used as a collusive device by banks. Banks choose the interchange fee collectively under a constraint of no profitable deviation to one-way compatibility. When the number of banks is small, the difference of consumers' valuations between the shared network and the proprietary network is not large, and a small interchange fee must be chosen to deter unilateral deviations. When the number of banks becomes very large, the difference is larger and switching to one-way compatibility is more difficult for banks. In this case, banks choose a high interchange fee and the number of ATMs deployed is over optimal. Under general conditions, the model predicts that, the larger the number of banks or the smaller the deployment cost, the higher the interchange fee collectively chosen by banks. This finding is consistent with empirical observations that interchange fees have not decreased when new operators have entered the ATM market and/or when deployment costs have decreased. The predictions of the model are also consistent with observed cases where the foreign fees are set above the interchange fees. Interestingly the model predicts that the equilibrium number of ATMs induced by the joint choice of the interchange fee is not necessarily distant from the optimal number if the number of banks is not too large. Recently, the Australian competition commission has suggested to drop the interchange fees and replace them by a system of direct charging. In a work that is complementary to ours, Massoud and Berhnard (2001) show such a system lead a an overoptimal number of ATMs deployed even if there are only two banks. Hence, there is no clear argument that a system of direct charging performs better than a system with interchange fees.

Our work could be extended into several directions. First, one could extend the analysis to take in account a more general demand for foreign withdrawals when analyzing the impact of foreign fees. The possibility of surcharging could also be considered. Salop (1990) and McAndrews (2001) have shown that a system in which there are an interchange fee, surcharges, and foreign fees leads to the neutrality of the interchange fee which becomes a less important tool.[13] Second, in our model, the interchange fee is multilateral and reciprocal. In some countries, there are different levels of interchange fees according to the difference between the deposit market share and the proportion of withdrawals processed. Future works could try to model the setting of non reciprocal interchange fees. In this case, one can think that low interchange fees could be used to deter entry of non-banks.

[13]In their framework, neutrality means that at equilibrium, banks' profits and the total ATM usage fee, that is the sum of the surcharge and foreign fee, are not affected by the interchange fee.

APPENDIX

Proof of proposition (7)

We prove that the strategies constitute a subgame perfect equilibrium. The equilibrium of the model is constructed so that the situation in which all banks choose foreign fees below the level $\overline{f}$ is a Nash equilibrium of the subgame following *any* profile $(n_1, ..., n_b)$.

It must be the case that given a deployment $(n_1, ..., n_b)$, bank i cannot profitably deviate to a foreign fee $f_i > \overline{f}$. It is clearly the case if $(n_1, ..., n_b) = (\frac{a^*-s}{c}\frac{b-1}{b^2}w, ..., \frac{a^*-s}{c}\frac{b-1}{b^2}w)$. Consider a profile $(n_1, ..., n_b) \neq (\frac{a^*-s}{c}\frac{b-1}{b^2}w, ..., \frac{a^*-s}{c}\frac{b-1}{b^2}w)$. In this case, $a(n_1, ...n_b) = s$, which means that each bank i is equally off between processing the withdrawals of its cardholders and paying the interchange fee associated to foreign withdrawals. In this case bank i cannot increase its profit by choosing a foreign fee f_i above $\overline{f}$. Indeed, the extra withdrawals processed by bank i do not increase its profits and clearly, bank i cannot increase the fixed part of the tariff because of the restrained access to cash.

Now, we verify that each firm i has no incentive to deviate at the deployment stage given that full compatibility will be chosen at the pricing stage. The profit when there is no (unilateral) deviation from $\frac{a^*-s}{c}\frac{b-1}{b^2}w$ is $\frac{t}{b^2} + \frac{a^*-s}{b^2}w$. The profit when deviating unilaterally to n_i is $\frac{t}{b^2} - cn_i$. Clearly deviating is not profitable.

References

[1] Ardizzi, G. and Coppola G. 2002. The Italian case study: interchange fee, market structure and cost efficiency in the retail payment system. Mimeo

[2] Armstrong, M., 2002, The theory of access pricing and interconnection, in Handbook of telecommunications economics, eds. M. Cave, S. Majumdar and I. Vogelsang, North-Holland.

[3] Bolt, W., 2003, Retail Payments in the Netherlands : some facts and some theory, Working Paper, De Nederlandsche Bank.

[4] Cruickshank, D., 2000. Competition in UK Banking : A report to the Chancellor of the Exchequer. Banking review.

[5] Ganguly B. and Milne A., 2001. Retail Payments in the UK : is there a problem of lack of competition ?. Working Paper, City University Business School.

[6] Laffont, J.J., Rey, P. and Tirole, J., 1998. Network competition: I. Overview and nondiscriminatory pricing. RAND Journal of Economics, Vol. 29, pp 1-37.

[7] Laffont, J.J., Rey, P. and Tirole, J. 1998. Network competition: II. discriminatory pricing. RAND Journal of Economics, Vol. 29, pp 38-56.

[8] Link Network. www.link.co.uk

[9] Massoud, N. and Bernhardt, D., 2001. Endogenous ATM Concentration. Mimeo, School of Business, University of Alberta, Canada.

[10] Massoud, N. and Bernhardt, D., 2002. Rip-off ATM surcharges, RAND Journal of Economics, Vol. 33, pp 96-115.

[11] Matutes, C. and Padilla, A.J., 1994. Shared ATM networks and banking competition. European Economic Review, Vol 38, pp 1113-1138.

[12] McAndrews, J.J., 1998. ATM Surcharges, Current Issues in Economics and Finance. Federal Reserve bank of New York. Volume 4, Number 4.

[13] McAndrews, J.J., 2001. A model of ATM pricing, foreign fees and surcharges, mimeo, Federal Reserve Bank of New York.

[14] McAndrews, J.J., 2003. Automated Teller Machine Network Pricing - A Review of the Literature. The Review of Network Economics. Vol 2, Issue 2, pp 146-158.

[15] McAndrews, J.J. and Rob R.,1996. Shared ownership and pricing in a network switch. International Journal of Industrial Organization. Vol 14, pp 727-745.

[16] Reserve Bank of Australia and Australian Competition and Consumer Commission. 2000. Debit and Credit Card Schemes in Australia: a Study of Interchange Fees and Access. Mimeo, Canberra.

[17] Rochet, J.C. and Tirole, J., 2002. Cooperation among competitors: some economics of payment card associations. Rand Journal of Economics. Vol 334, pp 1-22.

[18] Salop, S., 1979. Monopolistic competition with outside goods. Bell Journal of Economics, Vol 10, pp 141-156.

[19] Salop, S., 1990. Deregulating self-regulated shared ATM networks. Economics of Innovation and New Technology, Vol 1, pp 86-96.

Figure 1: determination of n^*